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Partial Replacement of Fine Aggregates by Lathe Waste in Concrete Interlocking Paving Blocks to Improve Desired Structural Characteristics

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ABSTRACT

Turning, milling, drilling, grinding and boring operations using lathe and other types of CNC machines are essential manufacturing processes of most steel or any other alloy related production works. Due to the above operations, considerable amount of waste material, commonly called as “Lathe waste” are generated worldwide. Usually, this waste product is disposed to the environment in an unhealthy manner without an effective usage. As lathe waste consists of considerable amount of steel fibers, there is possibility to improve desired structural characteristics of concrete products by adding this waste product by an appropriate amount. This study has focused on partial replacement of fine aggregates by lathe waste in concrete interlocking paving blocks to improve desired structural characteristics. As interlocking paving blocks may be subjected to flexural and tensile stresses due adverse environmental and operational condition in addition compressive stresses, which usually governs the design, the addition of lathe waste would be highly beneficial. Identification of appropriate mix proportion for partial replacement of fine aggregates in concrete interlocking paving blocks through an experimental study is discussed in this paper

Keywords: Lathe waste; concrete interlocking; paving blocks; Steel fibers

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1. INTRODUCTION

Concrete interlocking paving blocks made of concrete is a popular flexible treatment option for pavements (sidewalks), pedestrian precincts, parking lots, outdoor areas of residencies, and even in places that receive heavy wheel loads, like driveways, airports, warehouse pavements and road surfacing as well. Factors like fast assembly, possibility of easy replacement, enhanced rainwater infiltration, easy handling, fast production, aesthetically pleasing appearance, and availability in

wide variety of colors, patterns, models have popularized the usage of concrete interlocking paving blocks worldwide.

However, achieving desired structural characteristics of concrete interlocking paving blocks is essential as these are normally subjected to heavy vehicular loading and extreme weather conditions. Compressive strength is the main conventional structural check that is carried out relevant to concrete interlocking paving blocks. If the subbase of

a paving is properly constructed, it can expect a compressive stress in blocks and hence, structural compliance of a block can be checked through a compressive strength check. Accordingly, as per local standard for concrete interlocking paving blocks (SLS 1425-Prat I :2011[1]), the main structural/mechanical check that shall be carried out is compressive strength test.

Nevertheless, due to local unevennesses in subbases, thermal and other environmental effects, interlocking paving blocks may be subjected to flexural and tensile stresses. Hence, certain standards such as Indian Standard (IS 15658: 2006 [2]) has specified the tensile splitting strength test and flexural strength test for interlocking paving blocks in addition to the compressive strength test. The importance of these test has also identified by the SLS 1425-Prat I :2011[1], it has mentioned about the intention of introducing tensile splitting test for the standard in near future.

Introduction of some form of fibers to concrete has reported to be increased the flexural and tensile capacities of concrete by various research [3-5] due to balancing of stresses by transmitting tensile forces to the steel fibers which runs across the cracks that are developed as a result of tensile stresses.

As per literature data [6], the amount of annual global lathe and CNC waste produced is 1200MT per year and amount of lathe waste produced by a lathe machine is about 3-4 kg per day. The content of this waste product would consist of steel fibers and fine particles. Usually, most of these waste materials are disposed without using for meaningful purpose especially in Sri Lankan context. The potential hazard of contaminating ground water and soil by heavy metals due to disposal of waste of steel related industries have been highlighted by various literature [7,8]. Accordingly, effective utilization of these lathe waste has become a timely need to minimize environmental pollution and sustainable utilization of materials. Hence, this research has focused on the possibility of using lathe waste for partial replacement of fine aggregates during production of

concrete interlocking paving blocks to improve structural/mechanical properties of the product.

There are few previous research focused on the usage of lathe waste to improve properties of concrete. According to a study carried out by Shrivastavaa & Joshib (2014) [3] by adding lathe waste scrap for concrete (used for road paving work), compressive strength, split tensile strength and the flexural strength have been increased with the addition of lathe waste up to 1.5% of cement content of the mix. When the lathe waste percentage is higher than 1.5%, above strength of concrete has decreased. Another research carried out by Abbas (2011) [9] regarding addition of lathe waste to concrete has highlighted that addition of steel fibers would increase the compressive strength of concrete. Bharathi et al (2018) [4] has also highlighted that the optimum lathe waste content to improve compressive and split tensile strength of grade 30 concrete is 1.5% in their research on Lathe Waste fiber Reinforced Concrete. However, none of the above findings would be directly applicable for usage of lathe waste for concrete interlocking paving block as the concrete mix used for paving blocks are considerably differs from conventional concrete especially due to usage smaller coarse aggregates compared to conventional concrete. According to a study conducted by Babangida et al (2021) [10], the maximum aggregate size has considerably affected on compressive strength of 1:2:4 concrete. When it has been restricted the maximum size of coarse aggregates to 10mm, the highest compressive strength of concrete has been reported and it has reduced with the increase of coarse aggregate size. Another study done by Albarwary et al (2017) [11] on variation of compressive strength with various mix proportions also indicated that the maximum aggregate size strongly influences on the concrete strength. Results of these studies justify the need of detailed experimental study to identify the optimum lathe waste percentage if it intended to use it for concrete interlocking paving block production due to the usage of smaller coarse aggregates in concrete mixes used for interlocking block production.

2. MATERIALS AND METHODS

According to the SLS 1425- Part I :2011[1], there are four(04) strength classes for concrete interlocking paving blocks. Strength class 1 to 3 has been recommended for vehicular traffic and strength class

4 has been recommended for pedestrian traffic. Paving blocks comply with strength class 3 is the most commonly used paving blocks for domestic and other relevant applications, where it subjects to light

vehicle traffic. Hence, this study was focused on strength class 3. The average compressive strength requirement to comply with the Strength class 3 is 30N/mm². Based on the DoE method and the design approach adopted in Baskaran & Gobinath (2013) [12], the mix design was developed to comply with the strength class 3. The maximum size of course

aggregates was limited to the 12mm as specified in Indian standard for IS 15658:2006 [2] even though such limit is not specified in SLS 1425- Part I :2011 [1]. The maximum size of course aggregates is limited to the same size range in the present industrial practice too. The developed mix design is given in [table 1](#).

Table 1. Mix design for Strength class 3 concrete interlocking blocks

Specified strength (N/mm ²)	Cement (kg/m ³)	Fine Aggregates (kg/m ³)	Coarse Aggregates (kg/m ³)	Water (kg/m ³)
30	348.8	706.5	1193.2	202.9

Amount of fine aggregates specified in [table 1](#) were partially replaced by lathe waste as specified in [table 2](#) to identify the optimum partial replacement ratio.

The detailed mix proportions of considered trial mix are also presented in [table 2](#).

Table 2. Considered mix proportions for experimental study

Type	Cement (kg/m ³)	Fine Aggregates (kg/m ³)	Coarse Aggregates (kg/m ³)	Water (kg/m ³)	Lathe waste %
Mix 1	348.8	706.5	1,193.2	202.9	0.0
Mix 2	348.8	684.0	1,193.2	202.9	1.0
Mix 3	348.8	672.8	1,193.2	202.9	1.5
Mix 4	348.8	661.5	1,193.2	202.9	2.0
Mix 5	348.8	650.3	1,193.2	202.9	2.5

The maximum width and length of the lathe waste particles were maintained at 3mm and 5mm respectively in each trial mix. It was decided to use 220mm x 110mm x 80mm (Length x Width x Thickness) standard size Non Rectangular shape

blocks complied with SLS 1425- Part I : 2011[1] for this study. The typical shape of the block is shown in [Figure 1](#). [Table 2](#) Considered mix proportions with partial replacement fine aggregates by Lathe waste.

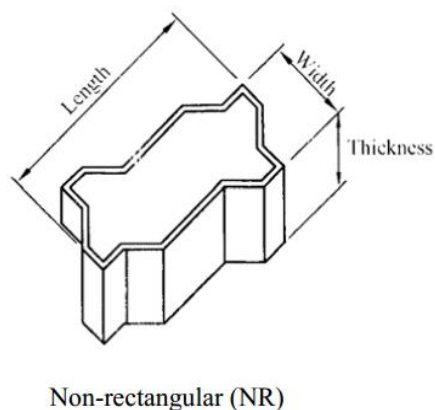


Figure 1. Typical shape of the block considered for the study

To produce test samples of the study, the following basic materials were selected with the compliance of the relevant standard as listed below:

Cement

A fresh Ordinary Portland Cement (OPC) complies with SLS 107 :2015 [13] was selected. The strength class of the Portland cement is 42.5 N/mm².

Fine Aggregates

Natural river sand was selected as Fine aggregates. Compliance of the Fine aggregates with BS 812-1:1991[14] was ensured by executing Sieve analysis test and other relevant checks.

Coarse Aggregates

Natural uncrushed chip aggregates, which range between 5-10mm of size were used. The specific

gravity of Course aggregates was 2.73. Compliance of material with BS 812-1:1991 [14] was ensured in this case as well.

Water

Ordinary tap (drinking) water was used throughout the work of this study.

Additives

Neither additives nor pigments were used in this study.

In case of lathe waste, it was selected macro size lathe wastes particles having thickness of 0.45-1mm and maximum length of 5mm. [Figure 2](#) shows a photograph of lathe waste sample used for this study.



Figure 2. A photograph of lathe waste sample

Production of the interlocking paving was done using a Concrete paving block making machine as shown in [Figure 3](#). Standard molds used with the machine were used for the production. Water/Cement ratio

was maintained at 0.54 as per the mix design. It was maintained mechanical vibrations of about 20 seconds using the above-mentioned production machine during the casting.



Figure 3. Block production machine & mold used for production of paving blocks

3. RESULTS AND DISCUSSION

3.1. Compressive strength

To observe the effect of introduction of lathe waste on compressive strength of paving blocks, standard compressive strength tests of samples at 7 days and at 28 days were carried out as per SLS 1425-part II: 2011 [15]. [Figure 4](#) shows the average compressive strengths at 7 days in graphical form. [Figure 5](#) shows the average compressive strength results at 28 days. According to the above results, a similar variation pattern can be observed at both 7 days and 28 days

test results. The maximum average compressive strengths in both cases were observed in case having lathe waste percentage of 2%. The percentage increase of compressive strengths at 7 days and 28 days with lathe waste percentage of 2% from control sample is 7.5% and 3.8% respectively. Average compressive strengths reported in all other samples with lathe waste are less than the average compressive strengths of control sample.

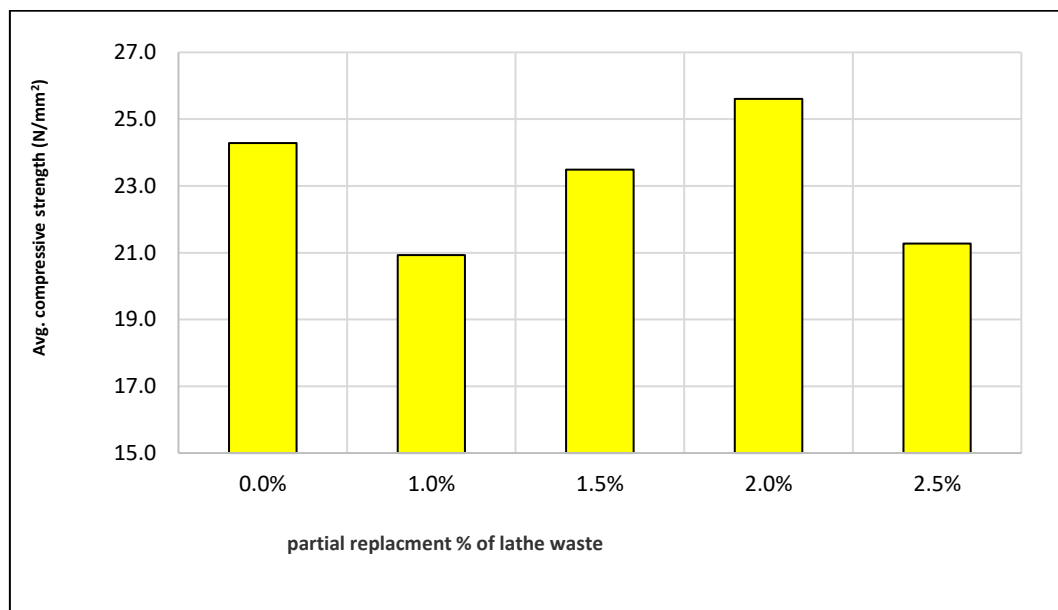


Figure 4. Variation of Avg. 7-day compressive strength of samples

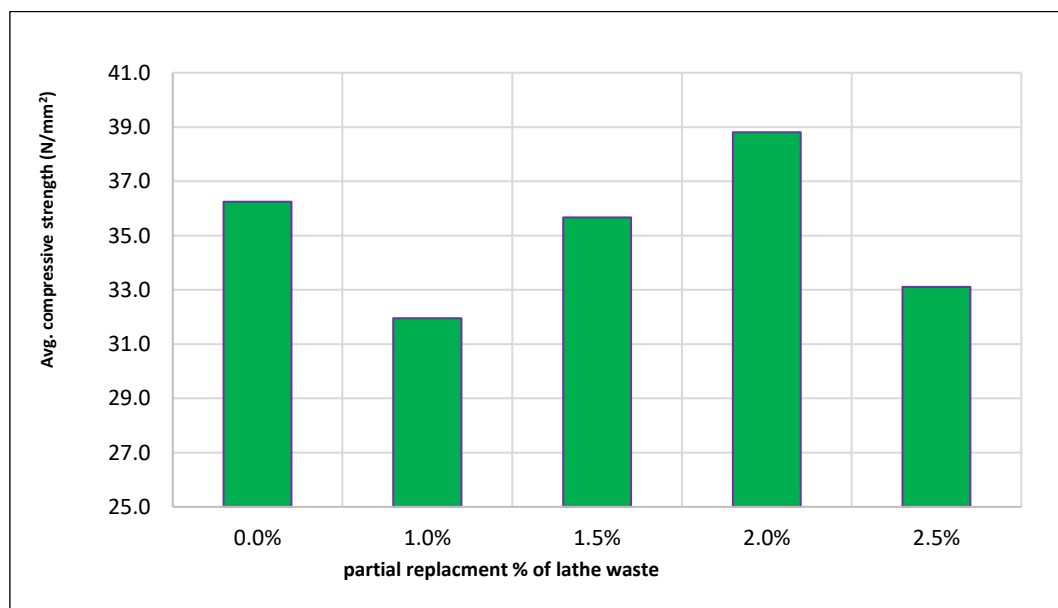


Figure 5. Variation of Avg. 28 days compressive strength of samples

This type of inconsistent variation of compressive strength test results has been reported by previous studies [6,9] as well. As the combine effect of fibrous nature of certain lathe waste particles and effect lathe waste addition on particle size distribution of fine

aggregates effect on the compressive strength of concrete, this type of inconsistent variation of strength would have been reported, when it is varying lathe waste percentages in mixes.

3.2. Splitting Tensile Strength

To observe the effect of usage of lathe waste for partial replacement of fine aggregates on tensile strength of paving blocks, splitting tensile tests samples were performed as per Indian standard IS

15658:2006 [2]. Figure 6 shows the test set up and a sample after the test was carried out as per the above standard.



Figure 6. Test setup of splitting tensile test and a sample after the test

Results of tests are presented in Figure 7 in graphical form. According to the results, splitting tensile strength has increased with increase of lathe waste percentage. The maximum average splitting tensile strength of 2.69N/mm² has been reported in samples with 2.5% of lathe waste and percentage increase from control sample is high 77%. Sample with 2% of

lathe waste has also showed 63% increase from results of control sample. Balancing of stresses by transmitting tensile forces to the steel fibers which runs across developing cracks may be the reason for the increase of splitting tensile strength with the increase of lathe waste percentage.

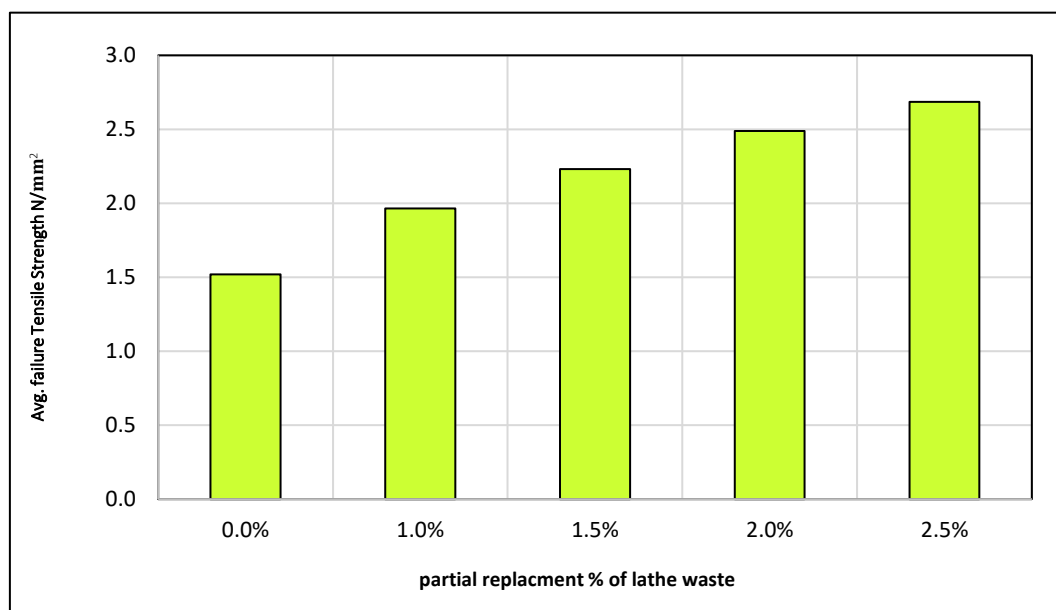


Figure 7. Variation of splitting tensile strength of samples

[Figure 8](#) shows a zoomed photograph of a split interlocking block with 2% of lathe waste. It can observe randomly located steel fibers (marked by red circles) of lathe waste at this split surface. As already

discussed, these fibers would have positively contributed to the increase of splitting tensile strength with the increase of lathe waste percentage.

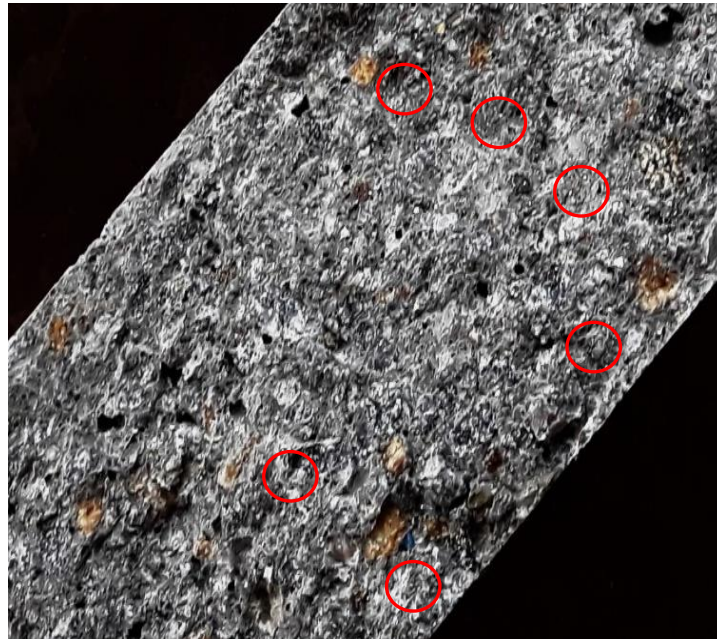


Figure 8. Presences of steel fibers at split surface

3.3. Flexural strength

Testing of flexural strength of samples was also carried out as per IS 15658:2006 [\[2\]](#). The test set up

used for the testing is shown in [Figure 9](#).



Figure 9. Test set up used for flexural strength testing

Increase of flexural strength was observed with the partial replacement of fine aggregates up to 1.5% by lathe waste and reduction of strength was observed when it was further increasing lathe waste percentage as presented in [Figure 9](#). Segregation of steel fibers while weakening the compressive strength in

compression zone with the increase of lathe wastage percentage beyond 1.5% may be probable reason for this observation. The maximum average flexural strength reported was 9.89 N/mm² (in sample with 1.5% of lathe waste) and it is a 76% increase from the flexural strength reported in the control sample.

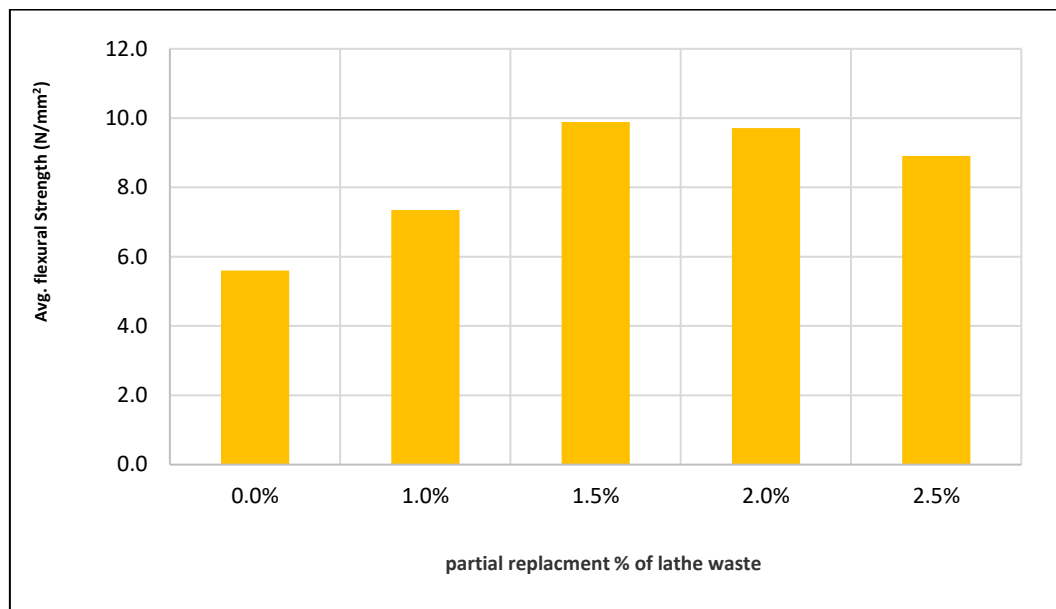


Figure 10. Variation of flexural strength of samples

Sample with 2% of lathe waste has shown a second highest flexural strength of 9.72N/mm². Therefore, when considers in overall strength perspective considering compressive strength, splitting tensile

strength and flexural strength of concrete interlocking paving blocks, the best partial replacement percentage of. fine aggregates by lathe waste would be 2%.

3.4. Water absorption and self-weight

As per SLS 1425- Part I : 2011 [1], it is required to control the water absorption less than 6% for the conformity. Accordingly, water absorption of samples with different lathe waste quantities were tested as per SLS 1425- Part I : 2011[1] and results are presented in Figure 11.

According to the test results, Samples having percentage lathe waste of 1% and 1.5% violate the standard requirement specified the Sri Lankan

standard. Especially, samples having 1% lathe waste have exceeded the limiting value by a fair margin.

Average self-weights of samples were also analyzed and presented in graphical form in Figure 12. It can identify a clear relationship between the variation of self-weights and the variation of water absorption. Understandably, exact opposite behaviors can be observed between these two results.

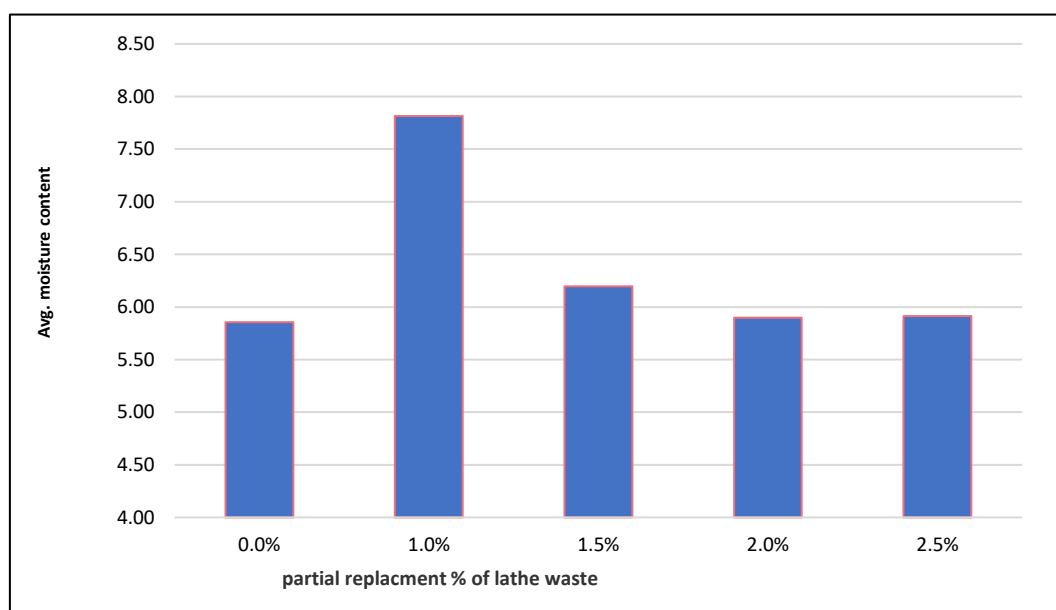


Figure 11. Variation pf moisture content of samples

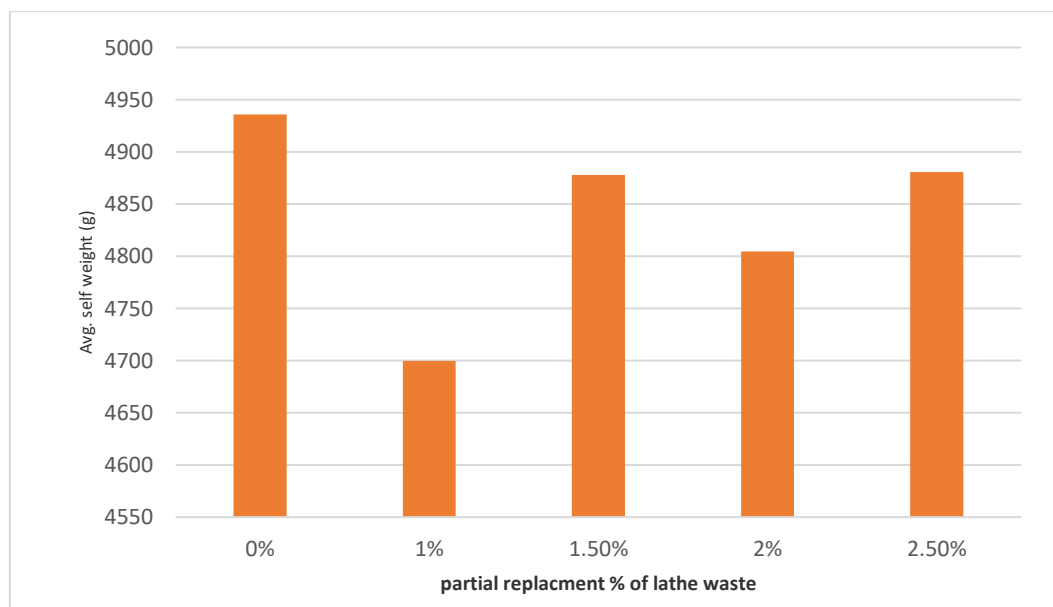


Figure 12. Variation of avg. self-weight of samples

Accordingly, the highest moisture content and lowest self-wight was observed in samples where lathe waste percentage was 1%. Availability of excessive amount of voids probably due to undesirable particle distribution of fine aggregates with the partial replacement of fine aggregates by lathe waste (1% of wight of fine aggregate of control sample) would be the probable reasons for this observation. However, it can confirm this as study was not focus on detailed analysis of finding root cause for this observation. Incidentally, the lowest average strengths (compressive, splitting tensile and flexural strengths) were also reported in samples having same amount of lathe waste other than control samples. Excessive amount of voids may be reasons for lesser strength as

well in these samples. Similar observation had been reported by Krzywińskic et al (2019) [16] in their research on the effect of the concentration of steel fibers on the properties of industrial floors.

However, samples with 2% of lathe waste, where it has shown most desired strength characteristics compared with control samples, have also shown lesser self-wight compared with control samples. The percentage reduction of average self-wight of samples with 2% of lathe waste from control sample is about 2.65%. This may facilitate slight advantage in handling and transportation of these paving blocks over conventional paving blocks, even though it is not significant.

4. CONCLUSION

The main aim of this study was studying the possibility of improving structural/mechanical properties of concrete interlocking paving blocks with partial replacement of fine aggregates by lathe waste, which is presently disposing without using for any meaningful application in the country. According to the results of the study, it can clearly observe that partial replacement of fine aggregates by lathe waste would improve mechanical/structural properties of conventional concrete interlocking paving blocks if the partial replacement is carried out by an appropriate portion. Replacement of 2% fine aggregates of it's weight in conventional mix by lathe waste has provided most desired strength characteristics (for blocks compiled the strength class

3 of SLS 1425- Part I : 2011[1]) ,when it considers compressive strength, splitting tensile strength and flexural strength of blocks. Further, the same mix has satisfied water absorption control limit specified in the local standard for concrete interlocking paving blocks and it provides slightly less self-weight compared with conventional mix. Therefore, it can recommend to use lathe waste for partial replacement fine aggregates of concrete interlocking paving blocks with the above mentioned proportion as it enhances the mechanical/structural properties of paving blocks while proving effective avenue for re use of lathe waste, which is presently disposing quite ineffective manner even causing environmental concerns.

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AUTHORS CONTRIBUTION

This work was carried out in collaboration among all authors.

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CONFLICT OF INTEREST

The author (s) declared no potential conflicts of interests with respect to the authorship and/or publication of this paper.

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